Competency 1.2 **Radiation protection personnel shall demonstrate a working level knowledge of the basic construction, operation, and theory of containment and confinement systems design.**

1. Supporting Knowledge and/or Skills

a. Describe and explain the radiological concerns associated with the design, construction, and operation of containment and confinement systems.

b. Describe the operational characteristics of containment and confinement systems that are designed to limit or prevent the release of radioactive material.

c. Discuss the design and operational characteristics of containment and confinement systems that minimize personnel radiation exposure.

d. Discuss the content and requirements of DOE Order 6430.1A, *General Design Requirements*, as they relate to the design and installation of radiation protection and contamination confinement systems.

2. Summary

DOE Order 6430.1A provides general design criteria for use in the planning, designing, or acquiring of a facility for DOE. When considering the radiological concerns associated with the design, construction, and operation of containment and confinement systems, the Order (p. 13-9) states, "special facilities shall be designed to minimize personnel exposures to external and internal radiological hazards, provide adequate radiation monitoring and alarm systems, and provide adequate space for health physics activities. Primary radiation protection shall be provided by the use of engineered controls (e.g., confinement, ventilation, remote handling, equipment layout, and shielding); secondary radiation protection shall be provided by administrative control. As Low As Reasonably Achievable (ALARA) concepts shall be applied to minimize exposures where cost-effective."

The basic ALARA philosophy can be described as limiting personnel and environmental radiation exposures to the lowest levels commensurate with sound economic and social considerations. However, the ALARA philosophy assumes that no radiation exposure should occur without a positive benefit, considering technological, economic, and societal factors. This statement implies that there is some risk, however small, with any exposure to radiation. One should always look for ways to reduce radiation exposure, as long as the cost of the consideration does not exceed the possible cost of the potential dose savings.

<u>One of the best ways to achieve ALARA is by designing it into a facility from the very beginning</u>**.** This ALARA engineering (or radiological engineering) ensures that radiation exposures are minimized when the facility goes into operation and that maintenance, repair, or modifications in the facility can be done safely and without significant contamination or radiation hazards.

Each facility will have its own unique set of concerns, so no list can be inclusive, but the following list of considerations for various aspects of building design can serve as a starting point for an ALARA review.

Crud Production and Radioactivity Deposition in Liquid Systems

- Reduce the loss of material from erosion by using good flow geometries and avoiding sharp bends, reducers, and rough internal surfaces.
- Reduce the loss of material from corrosion-resistant materials and by maintaining proper water chemistry.
- Reduce crud deposition by:
  - Providing crud filters, if practical.
  - Ensuring that all equipment is flushable and drainable.
  - Eliminating crevices, elbows, low points, and dead legs.

Airborne Radioactivity and Heating, Ventilation, and Air Conditioning (HVAC)

- Reduce airborne sources and gaseous leakage by:
  - Properly sealing and pressurizing equipment and ducts with such measures as continuously welded seams and flange gaskets.
  - Leak-testing HVAC equipment after installation and repair.
  - Selecting filters appropriate for the radioisotopes used and appropriate to the operation.
  - Avoiding filter breakthrough due to overloading by providing pressure sensors or monitors.

- Avoiding open-topped tanks or tanks with vent lines lower than tank overflow lines.
- Using good contamination control practices in designing for and performing such tasks as filter changeout, wet laydown of equipment, machining contaminated parts, etc.

- Use proper air flow:
  - To direct air flow from areas of low potential contamination to areas of greater potential contamination, and to exhaust from areas of greatest contamination.
  - Within a room, supply air to the cleanest area and exhaust to the most contaminated area.
  - To avoid drawing contaminated air across walkways, doorways, entrances, work areas, and especially breathing zones.
  - To ensure that the opening of doors, removal of shield plugs, etc., does not disrupt proper air flow.
  - To provide local ventilation such as hoods and spray booths where appropriate.
  - To be careful about pressurization of clean ducts that pass through contaminated areas, and vice versa, and about reversal of flow in ducts used intermittently.

Decontamination and Contamination Control

- Provide for proper contamination control measures by:
  - Selecting packless valves or those using live-loading packing.
  - Considering diaphragm or bellows-sealed valve designs.
  - Selecting pumps with mechanical rather than packless seals.
  - Routing pipe drains, tank overflow, valve stem leakage, etc., to sumps.
  - Sloping floors toward sumps or floor drains and using curbs, dikes, berms, and trenches as appropriate.
  - Considering whether flooding (due to leakage, backup of a sump, etc.) may cause the contamination of equipment and elevating such equipment above flood levels.
  - Avoiding open gratings for stairs or platforms in potentially contaminated areas.
  - Allowing room for friskers, stepoff pads, and used Contaminated-Zone (C-Zone) clothing bins outside contaminated or potentially contaminated areas.
  - Planning for eventual decontamination (e.g., if decontamination is done in place, the worker may be exposed to a high dose rate from other equipment in the area, or the worker may not have much room to work in, and the decontamination fluids, cloths, and removed parts will have to be collected. Therefore, the equipment may have to be removed for decontamination. If the equipment is removed to another location for decontamination, it may have to be bagged up, lifted and loaded, and moved along a path possibly passing through general access areas or areas of narrow clearance).

- Facilitate decontamination by:
  - Providing smooth, nonporous and nonreactive surfaces, whether inside equipment, on floors, on insulation, or for tools. Using appropriate coatings on floors, walls, trenches, doors, plugs, equipment, and tools.
  - Selecting equipment that can be readily and completely dismantled.
  - Making generous provisions for services for anticipated decontamination: water, air, electricity, and other connections.
  - Considering a central decontamination station for a large facility or operation; size, equip, and locate it for the types, sizes, number, and locations of the equipment it is to handle.
- Equipment decontamination
  - *The Radiological Health Handbook* (1970 ed., pp. 198-203) discusses methods of decontamination. Keep in mind that it is ALARA to select a method that reduces the dose to the worker (including both the direct dose and the airborne contributions), while reducing the volume of radwaste produced.

Radwaste

- Equipment
  - Never undersize a radwaste tank.
  - Select tanks with sloped or dished bottoms containing spargers or sprays.
  - Reduce crud deposition as mentioned earlier. Also use pipes with at least a 1½-inch diameter, long-bend radii, no right-angle bends, and sloping runs.
- Plugging
  - Avoid long vertical runs ending in a turn to the horizontal, as this leads to plugging.
  - Provide turbulent flow to eliminate homogeneity.

Sampling, Monitoring, and Instrumentation

- Sampling
  - Make sure that the sample is representative of the material sampled with respect to location, physical state, and chemical composition.
  - Provide sample lines that have few and large bends and are flushable.
  - Provide a strong and continuous purge of sample lines in high-radioactivity systems.
  - Locate sample probes at representative locations. They should normally be upstream and downstream of major filters, at all effluent and air monitor sampling points, and as needed in areas of potentially high airborne activity.
  - Locate grab sample taps, particle collectors, and sample filters appropriately. There should be no obstruction of any sample intake.
  - Carefully locate sampler intakes for breathing air in an open room, preferably no further than slightly above and in front of the worker's face.

- Monitoring
  - Provide sufficient and well-chosen radiation and air monitors to cover all areas where there is a potential for dose rates or airborne concentrations exceeding the limits of the respective areas.
  - Make sure that there are no obstructions or blocking of any monitor.
  - Process and effluent monitors should be located so as to have enough "detection lead time" to divert or isolate a process stream, if that is their function.
  - Provide friskers, portal, and "stand and count" monitors as recommended.
  - Make sure that all monitors have circuitry that can detect monitor failure automatically and indicate whether the dose rate is off-scale.
  - Provide readouts and alarms that are local, remote, or both, as appropriate. Make sure that the alarms are both visual and audible.
- Instrumentation
  - Locate all instrumentation, except for primary sensing elements, in low dose rate areas. Provide calibration from low dose rate areas, if possible.
  - Isolate instruments from contaminated fluids whenever possible.
  - Follow good practices for crud production to reduce buildup of radioactivity in instruments.

Access Control

- Traffic
  - Plan transport routes inside and between buildings so that nonradioactive material does not have to pass through radiological areas, and vice versa. Consider the sizes and locations of monorails, cranes, doorways, corridors, and hatches in order to achieve this.
  - Plan personnel traffic routes so that clean or general access areas are not isolated and can be reached without passing through a radiological area.
  - Be sure to consider the paths that firefighters will take in entering a radiological area. Try to provide paths that will keep them farthest away from areas of high dose rate while providing adequate access to the area of the fire.
- Radiological Areas
  - Make decontamination and radiation areas as small as possible.
  - Be sure each radiological area is properly posted and is provided with required locks, alarms, interlocks, etc. Use panic bars on the insides of locked doors as appropriate.
  - Minimize the number of access control points. Size them for the expected number of workers that will use them.
  - Provide space for temporary access control points where it is anticipated that they well be needed from time to time.
  - Provide personnel monitors as needed at each access control point.

Shielding, Penetrations, and Routing

- Shielding
  - Obtain information on shielding types and thicknesses from a radiological specialist (e.g., a radiological engineer, ALARA specialist, or health physicist, as appropriate for the project).
  - Consider temporary shielding when shielding would be needed only briefly or infrequently. Allow for space, support, and transport requirements.
  - Consider special shielding, such as shield doors, leaded glass windows, covers for hot spots, transport casks, and shielded carts or forklifts.
- Penetrations
  - Have all affected disciplines review a planned penetration before the hole is made.
  - Minimize the size and number of penetrations; several small penetrations are usually better than one big one.
  - Place penetrations:
    1) In the thinnest shield wall, near a corner, as high up as possible, and not in line of sight with a source.
    2) So that they do not line up with accessible areas, including stairways, doorways, and elevators.
    3) So that they do not line up with any radiation-sensitive equipment attached to a wall or ceiling on the low dose rate side of the penetration.
  - Consider offset penetrations.
  - Seal penetrations where justified, for dose rate reduction, air flow control, and leakage control.
- Routing of Ducts, Pipes, and Cables or Conduit (DPCs)
  - Have DPCs enter through a labyrinth or door, if possible.
  - Do not route DPCs containing contaminated fluids through general access areas, or clean DPCs through potentially contaminated or high dose areas.
  - Locate connections, pull spaces, junction boxes, panels, valve operators, taps, etc., in low dose areas or at least on the low dose rate side of the wall.
  - Provide as short a run of sample and other potentially contaminated lines as possible into the accessible areas.
  - Route clean and radioactivity-containing piping in separate areas, especially pipe tunnels; a worker servicing clean systems should not have to receive a dose.
  - Route so as to provide adequate clearance for maintenance, inspection, and insulation.

Proper Separation, Segregation, and Placement of Equipment

- Separation
  - Put shield walls between components sharing the same cubicle to reduce the dose to a worker maintaining one of them. The equipment should be placed so that the worker does not have to pass close to one to get to the other.
  - Passive equipment, such as tanks, should be separated by shielding from active or frequently maintained equipment.
- Segregation
  - Segregate highly radioactive equipment from moderately radioactive equipment, and both from clean equipment. Similarly, segregate equipment with high airborne potential from equipment with lesser airborne potential, and both from clean equipment.
  - Segregate radioactive equipment of different systems, so as not to have to flush, drain, or decontaminate both systems to reduce the dose when only one needs maintenance.
- Placement
  - Even with shielding, lay out equipment in an area or equipment cubicle so that as a worker enters, he/she progresses from low dose rate to moderate to high dose rate, and from active to passive equipment.
  - Place inspection, control, and readout devices and panels in low dose rate areas.
  - Place services (demineralized water, electricity, etc.) near entrances or at least in the lowest dose rate areas.
- Redundancy
  - Provide adequate redundancy and backup capability, especially in systems of high radioactivity content and safety systems.

Accessibility, Laydown, and Storage

- Accessibility
  - Allow adequate working space around major components, usually at least three feet.
  - Size labyrinths and doorways to allow the passage of workers, carts, forklifts, and tools, as appropriate.
  - Consider permanent galleries or scaffolding where maintenance is frequent or prolonged. Provide space and attachments for temporary structures if it is not.
  - Provide space for removal of filters into plastic bags of shielded containers.
- Laydown and storage
  - Provide laydown space in a low dose rate area.
  - Store hot tools (fixed contamination) and tools waiting for decontamination in appropriately posted, locked, shielded, and ventilated areas.

   - Properly store nonradioactive items (e.g., dosimeters, filters, insulation, etc.) to be used in radiological areas, so that they will not be degraded by radiation, light, moisture, etc.

Reliability and Equipment Qualification

- Reliability
  - Select equipment for ease and infrequency of maintenance.
  - Select equipment for length of service life under the expected conditions.
- Equipment qualification
  - Select materials that are qualified for the expected use, that is, which will not degrade unduly under the expected combined conditions of temperature, humidity, pressure, and especially radiation.

Human Factors

- Visual aids
  - Make sure that signs, indicators, readouts, etc., are clearly legible from a reasonable distance away. Use standard lettering.
  - Provide adequate lighting and consider auxiliary lighting where equipment is located in a corner or behind other equipment, or where remotely operated cameras are used. Provide automatic emergency lighting in areas where the dose rate may be elevated.
- Auditory factors
  - Provide alarms both numerous and loud enough to be heard everywhere in the subject area. Reduce the background noise.
  - Provide adequate communication measures, especially in areas where maintenance and inspection workers or health physics technicians may need to communicate with their supervisors or Health Physics during a job.
- Human physical characteristics
  - Familiarize yourself with an appropriate reference on human sizes and physical capacities. Apply this guidance to all design and operations work.
  - Consider the use of lifting devices and special tools to enable fewer workers to accomplish a job.
- Prevention of human error
  - Make permanent alignment marks on the equipment or floor; color-code tools, conduit, bolts, and piping; place identification on insulation to show what is underneath.
  - Clearly mark system lineup indication of valve position, breaker settings, and the like near controls of equipment.
  - Locate valves, valve operators, controls, etc., logically.

- Consider automation of operational sequences, or use interlocks and warning lights for dangerous choices in manual sequences. Also use interlocks as an aid to memory, such as starting a sample hood HVAC when the sample is being drawn.
- Make it cheap in terms of dose for operations to be accomplished safely. For example, in areas where the "buddy system" is used for safety, provide a low dose rate area where the watcher can observe, perhaps in the labyrinth entrance with a mirror.
- Use mockups and practice run-throughs.

3. Self-Study Scenarios/Activities and Solutions

Activity 1

Review

- DOE Order 6430.1A, *General Design Requirements*

Your facility has decided to start a new program; however, funds for this project will not allow for the construction of a new building. Therefore, an existing building must be modified/altered to house this program. The project will need a wet chemistry lab where millicurie and microcurie quantities of carbon-14, cesium-137, cobalt-60, gallium-68, iodine-131, and tritium will be used. There will also be classroom space, office space, a lunch room, and restrooms in this building. What are the radiological considerations that must be taken into account when revamping this building?

***Your Solution*:**

Activity 1, Solution
(Any reasonable paraphrase of the following is acceptable.)

Remember that each facility will have its own unique set of concerns, so no list can be inclusive, but following is a list of some important considerations for various aspects of building design that must be taken into account for this building.

The wet chemistry laboratory will need to be:

- preferably located in a far corner of the building.
- a separate room, controlled so that only authorized personnel have access.
- posted as a controlled area.
- specially equipped with items such as:
  - monitors and friskers
  - exhaust fume hoods
  - emergency showers
  - eyewash stations
  - spill control supplies
  - portable survey instruments, e.g., calibrated G-M pancakes.
- provided with proper air flow.
- provided with proper contamination control measures by allowing room for:
  - frisking
  - stepoff pads
  - used C-zone clothing bins.
- provided with smooth, nonporous and nonreactive surfaces (for ease of decontamination).
- provided with generous provisions for anticipated decontamination: water, air, electricity, and other connections.
- provided with standard lettered signs, indicators, readouts, etc. that are clearly legible from a reasonable distance away.

4. Suggested Additional Readings and/or Courses

Readings

- DOE Order 6430.1A, Referenced Documents Index, pp. 17-35.

Courses

NOTE: See Appendix B for additional course information

- DOE/EH-0450 (Revision 0), *Radiological Assessors Training (for Auditors and Inspectors) - Fundamental Radiological Control,* sponsored by the Office of Defense Programs, DOE
- DOE/EH-0450 (Revision 0), *Radiological Assessors Training (for Auditors and Inspectors) - Applied Radiological Control,* sponsored by the Office of Defense Programs, DOE
- *Applied Health Physics* -- Oak Ridge Institute for Science and Education
- *Health Physics for the Industrial Hygienist* -- Oak Ridge Institute for Science and Education
- *Safe Use of Radionuclides* -- Oak Ridge Institute for Science and Education
- *Radiation Protection Functional Area Qualification Standard Training* -- GTS Duratek

NOTES: